ORBITAL OPERATIONS STUDIES

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Technical Report No. 5

AN INITIAL USE-TEST OF TRIADIC DECIMAL DIGITS

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This report presents some results of an Orbital Operations Study being conducted by the Natural Resources Research Institute of the University of Wyoming under the general direction of Dr. John C. Bellamy and supported by Grant No. NsG 658 of the National Aeronautics and Space Administration. Dr. David Winkel, Director of the Computer Center of the University of Wyoming and Mr. David Fjeld of NRRI contributed significantly to the computer portion of the work.

Although this initial use-test indicates promise of the TRIADIC form of digits for some uses, it is not considered to have been demonstrated conclusively enough to warrant publication elsewhere for wider distribution at this time.

This report is a companion to a report, "A Traidic Decimal Digit Printer-Reader Unit, Preliminary Design Considerations" by C. N. Rhodine.

AN INITIAL USE-TEST OF
TRIADIC DECIMAL DIGITS

BRIEF

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AN INITIAL USE-TEST OF TRIADIC DECIMAL DIGITS

1. Purpose

When data are portrayed in the informatic forms, the identification of specific values within the data are sometimes difficult to determine readily. Thus, for these portrayals to be usefully complete, some method of labeling or identifying these specific values is necessary. The utilization of "TRIADIC" decimal digits for such a purpose as well as a discussion of these newly conceived digits is the primary purpose of this report.

2. Need

In review of the conception of informatic forms of data, the rapid advancements in all technological areas have greatly increased the amounts of data which must be effectively utilized. Clearly then, for this large amount of data to become most effectively useful, a presentation which has automatic quantitative recording and reading capabilities and still maintains qualitative manual recognition is desirable. That is, the presentation must satisfy the primary purpose of data, namely, to inform men with readily discernable qualitative and quantitative information.

The Arabic numerals (which are largely quantitative) appear essentially the same today as they did during the fifteenth century. The arrangement, size and contrast of the numerals have been changed to make them more distinctive, and thus, more accurately and easily read; but the numerals themselves have not been changed. The present form of these numerals seems to have endured for ease of writing; however, this does not necessarily postulate that they are the easiest to read. Large arrays of "Arabic" numbers have very little meaning in themselves to the reader, as such arrays require considerable translation by the reader to obtain a concept of their overall import. Thus in the past, the usefulness of any particular form of numerical notation has largely been determined by how convenient it was for man to form. However, with the advent of modern equipment, it is now possible to perform all kinds of numerical operations automatically. This possibility opens the way for portraying data utilizing numerals other than Arabic.

Toward this end, incremental forms of data are particularly applicable to "continuous" or "complete data." Complete data is that which presents all significant variations of an observation, or which represents a physical event which has been measured at intervals of sufficiently short durations to enable detecting all significant changes. In this sense, the term "significant" requires sufficient knowledge of the phenomenon being observed to permit assigning units of resolution that will be significant to the user. Complete data has the connotation of sequential completeness, which can best be described as "continuous data" or "data in which no two successive values differ by more than one unit of resolution used to form the data." That is, the difference between successive values is either one unit more than, the same as, or one unit less than the previous value. A "unit of resolution" has been defined[2] as "the smallest increment of a variable which is utilized, or which can be reliably resolved, in a quantitative representation of values of that variable." It is readily apparent that the unit of resolution of time or the ordinal variable is dependent on the unit of resolution of the dependent variable. It is also apparent that a number of factors are involved in the selection of an appropriate unit of resolution; the most important being the intended use of the data.

When data are portrayed in an incremental form, determination of discrete or particular values within the data block has been found to be difficult. In an incremental presentation the data are represented by a character representing one unit greater than, equal to, or one unit less than the preceding value. Clearly, with each of these increments (+, -, 0) represented by a unique recognizable character, only the relative value of a data point is identifiable. Thus for identification of discrete or particular values, it is necessary to develop some kind of scheme for labeling at least some of these particular values. Arabic numerals satisfy some of the general manual recognition requirements, but are not readily processed automatically. Thus, it is desirable that each decimal digit be represented by a unique notation that is both manually and automatically recognizable.

The Iadic[2] labeling technique is in the proper informatic format, but does not always satisfy the interpretation requirement for discrete values. This type of label indicates the magnitude and direction of the total change in value between points, but does not identify the value of discrete points unless there is a zero value reference point within the data. This zero reference point must also be readily identifiable. In some cases, the very nature of the data would identify the zero point; in others, the zero point would require an additional label. For example, if the data represented were something like the hourly precipitation[3] for a given place, the zero point is readily identifiable since it is the starting point of the data for a selected time period. The iadic label then denotes the magnitude of change which is, in this case, the same as the total amount of any given point in the time period and no further label is required.

For those cases where the initial point is not zero and the value is never zero, however, no discrete identification is possible with only the iadic label. It is therefore obvious that a digital label is also required for interpretation of the informatic representation of some types of continuous data. A similar kind of labeling system is also needed for the general identification of segments of the data as well as for discrete points within the data block.

3. "Iadic" Notations:

Specifically, the name "iadic" has been derived from its characteristic of utilizing "incrementally alternating dashes" to represent values of numbers. Consider the case in which the ordinal variable time is represented by a series of single incremental marks as shown on Figure 1. The number of hours of elapsed time since the beginning can quickly be determined by counting the number of changes from black to white in the series of long vertical dashes on the right of Figure 1. Also the number of half hour periods and number of five minute periods can be determined by counting the next two sets of vertical dashes respectively. This notation for designating values of time might well be called "biadic" since only two black and white levels of recording were utilized. This scheme is useful since we know beforehand that the values of time will always be increasing.

IADIC NOTATION

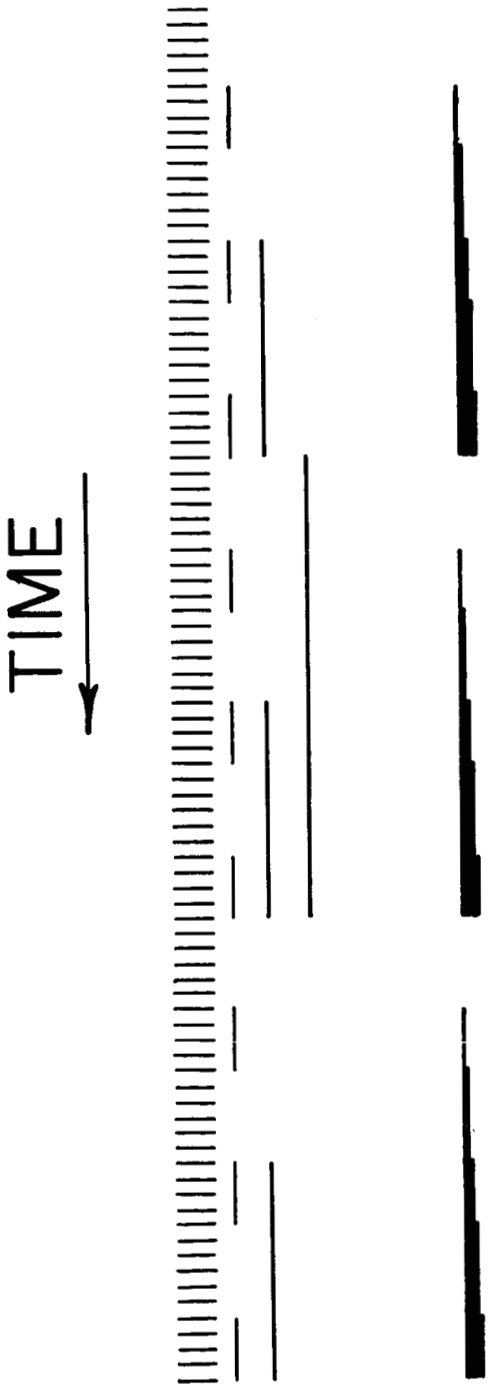


FIGURE 1

This same basic "incrementally alternating dash" technique can also be used to represent values which might either increase or decrease by utilizing more levels of recording. The example shown on the extreme right of Figure 1 uses six levels of recording, each level accounting for a five minute period. That is, the first change from full white (no mark) to a single width mark represents five minutes of elapsed time and the change from one width of mark to two widths represent another five minutes of elapsed time. Also the change from five widths of mark (full mark) to no mark represents thirty minutes of elapsed time. Any reversal of this sequence of change (such as a change from full five width mark to four width mark) indicates that the number of (5 min) units has algebraically decreased rather than increased.

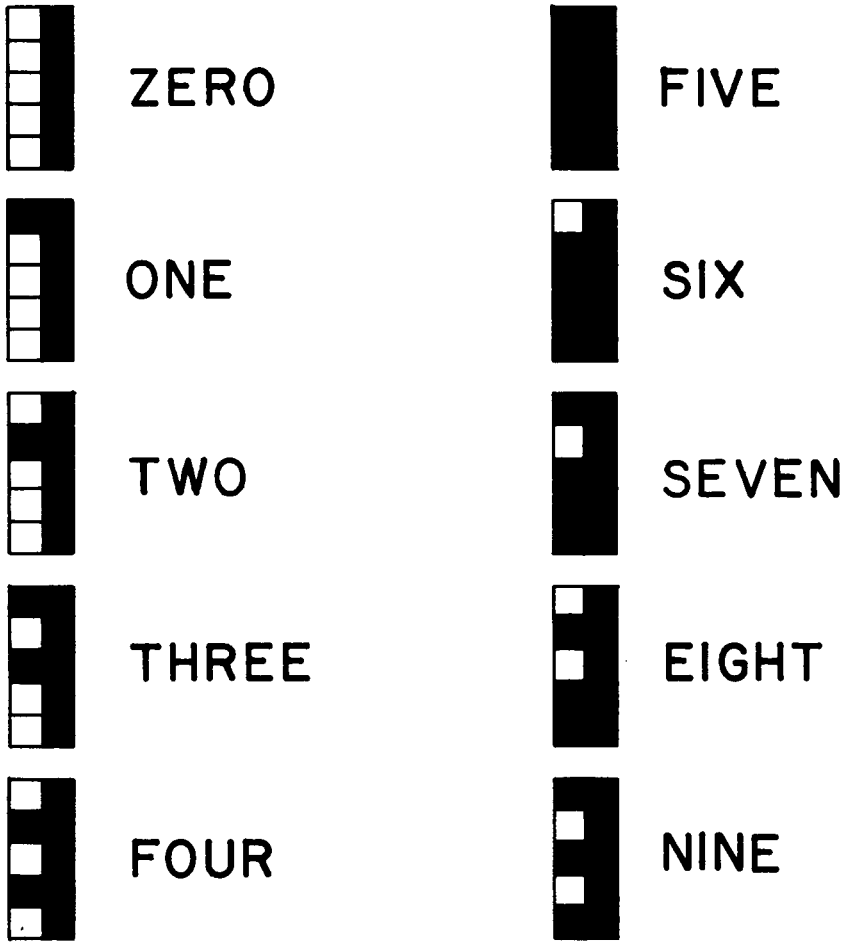
Iadic notations have the informatic characteristic of being readily recorded automatically. For example, they might well be recorded electro-graphyically with closely spaced, side-by-side stylii. Also automatic optical playback of such iadic notations is potentially quite convenient. Iadic notations also present both quantitative and qualitative information needed for manual recognition. They in short present the large scale distribution of the phenomenon being portrayed in usefully informatic form.

4. Definition and Automatic Characteristics:

Triadic numerals are formed with an iadic notation in which three varying widths of mark (including zero width of no mark) are used to represent the numbers zero through nine as defined in Figure 2. The sequence of variance of width in the triadic decimal digits is not uniformly progressive as in the iadic notation. Rather it is designed to produce the maximum definition of specific digits with a minimum complexity of automatic sensing of their values.

The value of each digit is countable by machine or manually as the number of width variations, including and referenced to the beginning and ending, zero-width values of the numeral itself. As illustrated in Figure 2, the digit groups 0 to 4 and 5 to 9 have been defined to be positive-negative complements so that their heights will not be excessive.

TRIADIC DECIMAL DIGITS



TWO BY FIVE NUMERAL SPACE

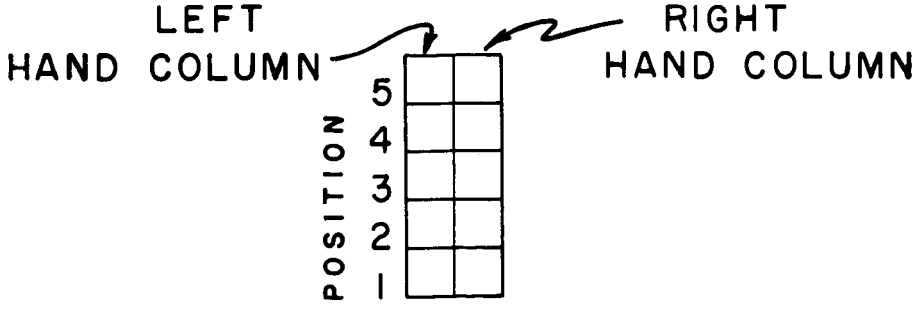


FIGURE 2

Specifically, the logic to be employed in reading these digits automatically could well be as follows.

(a) Scan the digit either from botton to top or top to bottom with a transverse optical slit.

(b) Count the total number of changes of width of the numeral, including the initial and final changes of width from and to zero-width.

(c) Determine whether the change in width at the bottom of the numeral is between zero and one unit of width or between zero and two units of width.

(d) The value of the digit is then equal to:

- the number of changes of width minus two if the bottom of the numeral is one unit wide
- the number of changes of width minus two plus five if the bottom of the numeral is two units wide.

A similar logic might well be used for automatically recording these digits as follows.

a.. Set the number to be recorded in a bi-quinary counter; that is, in a scale-of-five-units counter followed by a scale-of-two or binary counter.

b. Make the appropriate width marks in each of the five longitudinal mark-spaces of these numerals in sequence, starting with the bottom space and adding a unit count to the quinary counter upon making each such mark.

c. Make each successive mark:

- the same width as the previous mark if the quinary counter has not yet reached full scale (that is, has not yet changed from its four-state to its zero-state); or
- the alternate (of one or two units) width of the previous mark for all spaces after the quinary counter has once reached full scale.

d. Start this process by making the first, bottom, width of mark:

- One unit wide if the number to be recorded is zero, one, two, three or four, or if the binary counter is initially in its zero-state; or
- Two units wide if the number to be recorded is five, six, seven, eight or nine, or if the binary counter is initially in its one-state.

For example, the triadic decimal digit representing the number two would be recorded by first recording a simple width mark in the bottom space since the binary counter would be in its zero-state. Adding a unit count to the quinary counter would then change it to its three-state and (since it did not change from its four-state to its zero-state) a simple width of mark would also be recorded in the second space from the bottom. A single width would then also be recorded in the third space from the bottom since the quinary counter would by then have been advanced to only its four-state. The subsequent addition of a count would then advance the quinary counter from its four-state to its zero-state. Consequently the fourth mark from the bottom would be made double width (as the alternate of the single width in the third space), and the fifth mark from the bottom would be made single width (as the alternate of the double width in the fourth space).

A similar train of events would occur in recording the triadic decimal digit for the number seven. In this case, however, the initial or bottom mark would be of double width since the binary counter would be in its one-state. Consequently the first, second and third marks from the bottom would all be double width marks, the fourth mark would be of single width and the fifth would be double as illustrated in Figure 2.

5. Illustration:

In order to test the potential utility of these triadic kinds of decimal digits, the sample record in Figure 3 was formulated. For this test, a computer program was written for a Philco 211 computer to convert satellite coordinates of longitude, latitude and height into informatic

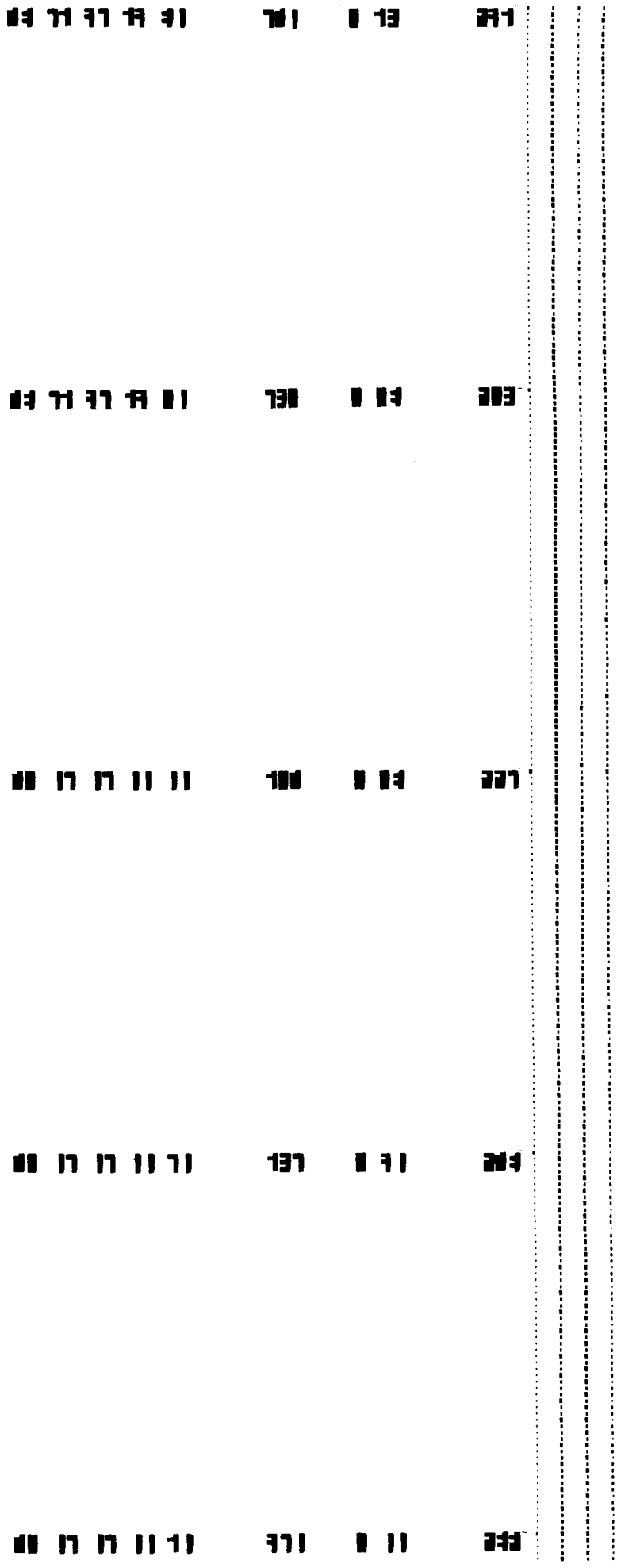


FIGURE 3

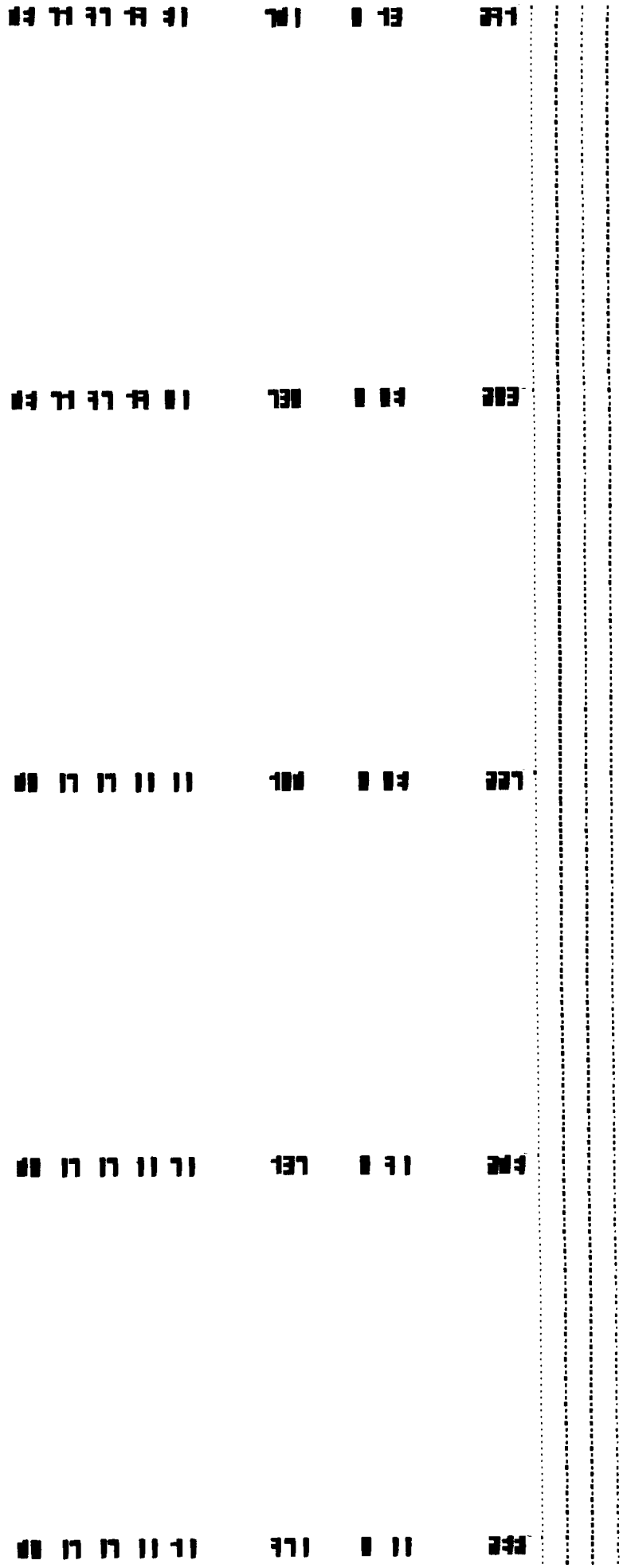


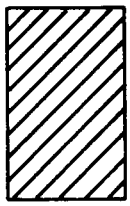
FIGURE 3

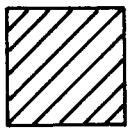
forms for several revolutions of the TIROS 8 weather satellite. The computational output was programed for punched paper tape and the record produced on a Friden Flexowriter typewriter. Special characters were machined for this typewriter to replace the necessary number of letters and the Arabic numerals with proper incremental numerals and the triadic decimal digits. In its final form the incremental portion of the record has been photo reduced by a factor of four while the triadic decimal digits on the label portion are the same size as produced by the typewriter. This size relationship is in keeping with the reading-writing logic discussed earlier.

In this test example, the ordinal variable, time, is represented by three informatic scaled incremental numerals indicating increases of one minute, ten minutes and one hour as defined in Figure 4. This notation is used to represent time in the first column of the incremental portion of the record and is labeled with the triadic decimal digit label each ten minutes. Similar numerals are used to provide an incremental notation for values of coordinates, but in this case they indicate one unit of resolution increase, no change, or one unit of resolution decrease (see Figure 4). The particular values of longitude, latitude and height which occur each ten minutes of time are labeled in the order indicated. In the case of the latitude, negative values in the triadic decimal label are preceded by a triadic five (5) and a space. In the case of longitude, west is differentiated from east by using a 360° system wherein all west values are represented as 360° minus the west longitude reading. Accordingly, all west longitudes are 180° and greater. The longitude, latitude and height notations are in column 2, 3, and 4, respectively, of the incremental portion of the record. The triadic decimal digit label portion of the record contains: first, the time label showing year, month, day, hour and minute in that order; second, the longitude in degrees; third, the latitude in degrees; fourth, the elevation in kilometers.

The unit of resolution for the computation was selected as being one degree for the latitude and longitude and one kilometer for height. The unit of resolution for time then had to be 10 seconds in order to obtain continuous data. Since observational data was available for one

INFORMATIC FORMS





VARIABLES	
COORDINATES	TIME INCREASES
UNIT INCREASE	1 HOUR
NO CHANGE	10 MINUTES
UNIT DECREASE	1 MINUTE

FIGURE 4

minute intervals, interpolation was required to generate the intermediate values at the required 10 second intervals. These were generated according to the following parabolic interpolation formula;

$$Y_{np} = Y_n + p\ (Y_{n+1}-Y_n) + \frac{p\ (p-1)}{2}\ (Y_{n+2}-2Y_n)$$

where the Y_n's are successive values of the specific cardinal variable and p is the reciprocal of the number (six) of increments desired between data points.

6. Evaluation

The experience gained in conducting this research has indicated that the triadic digits can readily be interpreted manually with only a short learning period. This being true, they have a clear potential advantage over Arabic numerals for at least some purposes since they can be machine processed much more readily.

On the other hand, the test sample of Figure 3 has clearly shown that the use of triadic decimal digits for periodically labeling "full" values of incremental data is not very advantageous. For example: the five-space height (or longitudinal length) of the triadic decimal digits is excessive for this kind of purpose; the empty spaces between successive lines of the periodic labels are completely wasted; and the correlation of values of periodic labels with values indicated in the incremental portion of the record is too difficult to be useful.

In addition, this first trial in Figure 3 of the use of an incremental form of data to portray the space-time coordinates of satellite positions is clearly not very satisfactory. In this case, however, the trouble arises more from the size and proportions of the incremental numerals used than from an inappropriateness of incremental notations for such positional information. The appearance of the incremental portions of this test record before they were photographically reduced in size strongly suggested that the desired concise "shades and shadows" portrayal of positional information can well be obtained with additional development.

7. Conclusions

In conclusion, this work has indicated that triadic decimal digits may well find an important place in automatic data processing in the future. Possible applications for orbital data might be to identify data sheets or large blocks of continuous data. Much more experimental use-testing is required, however, before their potential utility for such purposes can be confirmed.

In addition, it is concluded from this work that the use of informatic forms of data might very well provide useful portrayals of orbital position data for several purposes. Other work[3,4] which was being conducted at the same time indicates that the desired characteristics might well be obtained by (1) modifying the proportions of the incremental numerals, (2) utilizing a "scaled-incremental" notation to indicate the positions at which the values of larger digits change within the body of the incremental record, and (3) utilizing a "uadic" notation to label the values of the largest scale digits in a single parallel labeling column for each of time, latitude, longitude and height. It is planned to prepare a second test sample of orbital positional data in such a "SIPLIC" or "Scaled Incremental, Periodically Labeled, Incrementally Continuous" form as soon as recording devices capable of forming more appropriately proportioned numerals become available.

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